A Look-up-table Approach to Inverting Remotely Sensed Ocean Color Data

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Award Number: N0001400D01610001
http://www.onr.navy.mil/sci_tech/ocean/onrpgahk.htm

LONG-TERM GOAL

The overall goal of this work is to develop and evaluate a new spectrum-matching technique for inverting remotely sensed hyperspectral signals to recover environmental information.

OBJECTIVES

We are developing and evaluating a new technique for the extraction of environmental information such as water optical properties and shallow-water bottom conditions from remotely-sensed hyperspectral ocean-color spectra. Our technique is based on a "look-up-table (LUT)" approach in which the measured spectrum is compared with a large database of spectra corresponding to known water, bottom, and external environmental conditions. The water and bottom conditions of the water body where the spectrum was measured are then taken to be the same as the conditions corresponding to the database spectrum that most closely matches the measured spectrum. The research issues center on development and evaluation of spectrum-matching algorithms, including quantification of how various types of errors in the measured spectrum influence the retrieved environmental data.

APPROACH

The technique will be developed using Hydrolight-generated pseudodata and then applied to data sets taken during the CoBOP (Coastal Benthic Optical Properties) and HyCODE (Hyperspectral Coastal Ocean Dynamics Experiment) programs.

The Hydrolight radiative transfer numerical model (http:\\www.sequoiasci.com; Mobley, 1994; Mobley and Sundman, 2000a,b) gives an exact solution of the in-water radiative transfer equation given the water inherent optical properties (IOPs, namely the absorption and scattering properties of the water body), the incident sky radiance, and the bottom depth and reflectance (bottom BRDF). The water IOPs can be built up from any number of components, such as various microbes, dissolved substances, organic detritus, mineral particles, or microbubbles. For remote-sensing purposes, the relevant Hydrolight output is the spectral water-leaving radiance or the remote-sensing reflectance.

We will first construct a database containing a large number of Hydrolight runs corresponding to different combinations of water composition (different microbial, dissolved, or mineral substances at

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2001**	2. REPORT TYPE	3. DATES COVERED **00-00-2001 to 00-00-2001**

4. TITLE AND SUBTITLE **A Look-up-table Approach to Inverting Remotely Sensed Ocean Color Data**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Sequoia Scientific, Inc.,,Westpark Technical Center,15317 NE 90th Street,,Redmond,,WA, 98052**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

different concentrations), sky conditions (different solar angles and atmospheric conditions), sensor viewing directions, wavelengths, and so on. The resulting water-leaving radiances in the database, $L_{wd}(\lambda)$, are in principle all unique (but in practice may often be similar; λ is the wavelength). Given a measured water-leaving radiance $L_{wm}(\lambda)$ (obtained from atmospheric correction of an at-sensor radiance), one can then "look up" the $L_{wd}(\lambda)$ spectrum that most closely matches $L_{wm}(\lambda)$. The water IOPs and bottom conditions in the actual water body are then taken to be the values that were used in Hydrolight to generate the selected $L_{wd}(\lambda)$. We thus effect an inversion of the measured spectral signature by the conceptually simple process of spectrum matching and then looking up the answer in the database.

However, a significant problem of spectrum matching is the difficulty of finding the global (overall) best fit when there are many local best fits (i.e., many local minima in the function to be minimized). The recently developed method of simulated annealing has proved quite effecting at finding global minima in problems with many local minima (Press, *et al.*, 1992). Indeed, simulated annealing has effectively solved the famous “traveling salesman” problem in which the total distance traveled between *n* cities must be minimized. There is an obvious analogy between the total distance between *n* cities and the distance between measured and database spectra at *n* wavelengths. We are therefore optimistic that simulated annealing will be effective in solving the type of optimization problem that underlies spectrum matching.

WORK COMPLETED

This is a new project that is just now beginning. This year’s work consisted of defining a limited set of Hydrolight runs for use in constructing the initial part of the data base. This initial data base is designed for use in recovering shallow-water environmental information, such as bathymetry and bottom type. This shallow-water part of the data base will be used for initial algorithm development and evaluation. Subsequent additions to the data base will be for deeper waters and for a wider range of water column properties.

RESULTS

We do not yet have presentable results from our initial work. However, it is worthwhile to present some of the science issues that must be addressed in developing and evaluating the LUT approach to inverting water-leaving radiances:

- What is the best algorithm for deciding which L_{wd} spectrum most closely matches L_{wm}? How well do different algorithms separate close matches from the overall best match (local vs. global minima in the fitting function)? How should different wavelengths be weighted to de-emphasize wavelengths where the measured spectrum has larger inherent errors?

- How do errors in L_{wm} determine the errors in the retrieved environmental parameters? Different environmental parameters affect the water-leaving radiance in different ways, and therefore will be retrieved with different types and magnitudes of errors if the L_{wm} and L_{wd} match is not perfect. How do different types of errors, e.g. errors in overall spectral shape vs. errors at a few wavelengths, affect the retrieval of different environmental parameters?

- How much information is added to the LUT inversion when additional wavelengths are added to L_w? For what situations (retrieval of IOPs, bottom type, etc) is hyperspectral data demonstrably superior to multispectral data?

- How does the proposed LUT approach compare to other approaches (such as the band-ratios algorithms or derivative algorithms) for various environmental conditions (e.g., Case 1 vs. Case 2 waters; optically deep vs. optically shallow waters). What, in general, are the strengths and weaknesses of the LUT approach to ocean color inversion?

IMPACT/APPLICATION

The problem of extracting environmental information from remotely sensed ocean color spectra is fundamental to a wide range of basic and applied science problems. No single inversion technique can be expected to be superior in all situations; therefore all techniques must be evaluated. In addition to investigating a new type of inversion, part of our work is to evaluate when the LUT technique is superior to other techniques, and when it is not. This work thus adds to the existing suite of remote sensing analysis techniques.

TRANSITIONS

The initial data base and algorithm development are intended to support Dr. Curtiss Davis' (NRL Code 7212) exploitation of the Ocean PHILLS hyperspectral ocean color remote sensing system to retrieve bottom bathymetry and bottom classification information in optically shallow waters. The initial work now underway is intended for quick transition to NRL.

RELATED PROJECTS

This work is being conducted in conjunction with Dr. Curtiss Davis of NRL, who is separately funded under Hyperspectral Characterization of the Coastal Ocean (HCCO), and with Dr. Paul Bissett, who is separately funded at the Florida Environmental Research Institute.

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